number of tornadoes annually per State and per unit area. The table shows that even in the so-called tornado States, the probability that any area of 100 miles square will be visited by a tornado in any year, is generally less than certainty, or unity, or less than 100 per cent. If these large areas be divided up into 100 smaller ones of 100 square miles each, or 10 miles square, then the probability that *some one* of these will be visited by a tornado within a year is less than 1 per cent, but the probability that *any specific one* of these smaller areas will be so visited is only the hundredth part of 1 per cent per annum, or 1 per cent per century. Within such a smaller area of 10 miles square the destructive path of the tornado, when it finally comes, will probably cover less than 25 square miles, so that the probability that *some one* of the 100 areas of 1 square mile will be struck is less than one-fourth of 1 per cent per century; but for *any specific area* or farm of 1 square mile the probability is much less than one-sixteenth of 1 per cent per century. In fact, the probability that a given house will be destroyed by a tornado is less than the probability that it will be destroyed by lightning or fire.

THUNDERSTORMS AT EUSTIS, LAKE COUNTY, FLA.

The voluntary observer (Mr. H. W. O. Margary) at Eustis, Fla., sends a detailed record of the thunderstorms at his station during June. His location is about 28° 45′ N., 81° 40′ W; altitude 60 feet above Lake Eustis, which is supposed to be 120 feet above sea level; the range of his horizon is quite large, being most restricted on the south side by heavy timber, but to the eastward there is no known limit, as he has observed lightning belonging to storms far beyond the coast line, and, in one case, as far away as the Bahamas, 250 miles, on which occasion the lightning appeared like a small segment of a circle rising from 3° to 7° above the horizon. To the westward his horizon is level over the low swamps, lakes, and river valleys. The view in all directions is entirely uninterrupted for distances ranging between 2 and 7 miles.

With these ample surroundings the temptation to make a minute study of thunderstorms is very great; but, of course, elaborate work in this direction at only one isolated station loses a great deal of the value that would attach to it if similar records had been kept by other observers distant a few miles from the central station. Mr. Margary's record shows that thunder was heard on the 2d, 3d, 4th, 5th, 6th, 7th, 12th, 13th, 14th, 15th, 16th, 21st, 22d, and 24th, or, in all, fourteen days, on all which occasions it is presumed by him that the storm was within 3 or 4 miles of his station. Some details of these storms, especially the azimuths at which they appeared and ended, when compared with similar observations at neighboring stations, will eventually give the exact location and path of the center. Other data can be at once used to give us, for instance, the hours of the day at which thunderstorms occur most frequently, or the diurnal curve of frequency. Thus, during June, at or near Eustis, the prevalence of thunderstorms within each hour of the day seems to have been as follows:

Midnight to 1 a. m.	1	Noon to 1 p. m.	0
1 a. m. to 2 a. m.	0	1 p. m. to 2 p. m.	2
2 a. m. to 3 a. m.	1	2 p. m. to 3 p. m.	2
3 a. m. to 4 a. m.	2	3 p. m. to 4 p. m.	2
4 a. m. to 5 a. m.	1	4 p. m. to 5 p. m.	4
5 a. m. to 6 a. m.	2	5 p. m. to 6 p. m.	1
6 a. m. to 7 a. m.	0	6 p. m. to 7 p. m.	1
7 a. m. to 8 a. m.	2	7 p. m. to 8 p. m.	2
8 a. m. to 9 a. m.	2	8 p. m. to 9 p. m.	3
9 a. m. to 10 a. m.	0	9 p. m. to 10 p. m.	1
10 a. m. to 11 a. m.	0	10 p. m. to 11 p. m.	1
11 a. m. to noon	0	11 p. m. to midnight	1

As no cyclonic storms visited Florida during this month, it is evident that the special frequencies between 3 a. m. and 9 a. m., between 1 p. m. and 5 p. m., and between 7 p. m. and 9 p. m. must all be determined by the alternation from warm sunshine at midday to cool radiation at night.

So far as we can make out from this record, which was apparently not prepared for the purpose of a study from this point of view, the thunderstorms appeared six times in the northwest, five in the north, two in the northeast, two east, three in the southeast, two in the south, three in the southwest, one in the west. The direction of motion of the storms in their paths is not easy to make out from the records at a single station, but, so far as can be gathered, the prevailing motion is from the southwest to the northeast. Mr. Margary especially notices a few storms that "came up with the wind," while the general rule was that they should "come up against the wind," and, as the wind is usually northeast, this would also indicate that the thunderstorms advanced from the southwest toward the northeast.

MECHANISM OF THUNDERSTORMS.

The advance of a storm against the wind may be interpreted as favorable to that view of the origin and structure of thunderstorms that has lately been so fully elaborated by E. Engelenburg in his memoir on the "Aerodynamic Theory of Thunderstorms," published in the XIXth volume (1896) of the Selections from the Archives of the Deutsche Seewarte. According to this view (which has been frequently expounded by the Editor since 1871) a thunderstorm is the result of the overturning of a considerable mass of the lower atmosphere, by which cool and especially dry air descends and runs under and pushes up warmer, moister air, which latter, after losing a small percentage of its moisture as rain, and a good deal of its heat by radiation from the clouds, becomes in its turn again the heavier, and descends beneath other moist air. This process of descent and ascent constitutes a vertical rotation around a horizontal axis, and will continue indefinitely until the rolling mass of air comes into regions where the topography of the ground or the presence of very dry air or very cold air near the ground as in the early morning hours, breaks up the thermodynamic process that is essential to the storm's automatic propagation. In the course of this rotation around a horizontal axis, it may occasionally happen that the rotation which is never strictly vertical, becomes considerably inclined, and the winds become so severe that the storm is spoken of as tornadic; but the true tornado with its funnel-shaped cloud is not to be considered as belonging to this class of thunderstorms. Beside the rolling thunderstorm, which advances broadside forward, there is another class of storms to which the tornado and the waterspout belong. In this class of storms the motive power is found in the buoyancy of a great cumulus cloud under whose center the lower air ascends because it is pushed upward into the region of abnormal low pressure within the cloud. Another class of thunderstorms includes those formed by air that is pushed upward by being blown against obstacles such as mountains, these often have no special internal maintaining power and may soon die away.

FREQUENCY OF THUNDERSTORMS.

We have received from Mr. H. H. Moore, voluntary observer at Windsor (five or ten miles north of Hartford, Conn.), a record of the number of days on which thunder has been audible; it embraces all days on which thunderstorms were heard by the observer without regard to the distance of the storm. Mr. Moore's record can be thrown into the following tabular form so as to give the average for each month of the year:

Months.	1883.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.	1896.	Totals.	Annual mean.
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00
February	0	0	0	0	1	1	0	1	1	0	0	0	0	0	4	0.29
March	1	1	0	1	0	0	1	2	1	0	1	0	0	0	8	0.57
April	2	1	0	2	1	3	3	2	4	0	2	2	3	3	28	2.00
May	3	3	0	5	5	5	2	4	2	3	3	5	2	8	50	3.57
June	7	3	4	3	4	8	6	6	3	10	5	7	10	2	78	5.57
July	9	8	5	8	10	4	3	2	4	11	8	10	7	9	98	7.00
August	4	5	9	2	12	3	3	6	6	8	5	5	7	9	84	6.00
September	2	6	0	4	2	2	1	5	2	2	2	3	4	4	39	2.79
October	0	0	1	0	1	2	2	1	0	1	0	0	0	0	8	0.57
November	0	0	0	2	0	0	0	0	0	0	0	0	1	0	3	0.22
December	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2	0.14
Annual	29	27	19	27	36	28	21	30	23	35	27	32	34	35	402	28.7

This table apparently gives us a close approximation to the normal distribution of thunderstorm days in that locality. It will be noticed that we have here not the number of storms, but the number of days on which one or more storms occurred. The record does not include thunderstorms at an indefinitely great distance, but only those that were near enough to give audible thunder, and this rarely occurs when the storm is more than 10 miles distant; in fact a distance of 3 miles would appear to be a fair average for the storms here recorded.

The months in which thunderstorm days were most numerous were: August, 1887, 12; July, 1892, 11; July, 1887, June, 1892, July, 1894, June, 1895, 10. The average number for July was 7, and the average number for the whole year, 29. The maximum was 36 in 1887.

AUDIBILITY OF THUNDER.

The audibility of thunder depends not merely on the initial intensity of the crash, but equally on the surroundings of the observer, since in the quiet country one will observe feeble sounds that escape the ear in a noisy city. But perhaps the most curious and important condition of audibility is that the thunder, or wave of sound, shall not be refracted or reflected by the layers of warm and cold air between the observer and the lightning or by the layers of wind, swift above and slow below, so as to entirely pass over or around the observer. Sound is somewhat analogous to a wave phenomenon, and consequently is subject to refraction when it passes obliquely through layers of air of different densities. Such refraction may occur at any time and place. Thus observers at the topmast of a ship frequently hear fog whistles that are inaudible at sea level; those on hilltops hear thunder that is inaudible in the valley; those in front of an obstacle hear sounds inaudible to those behind it. The rolling of thunder, like that of a distant cannonade, may be largely due to special reflections and refractions of sound. Again, the greater velocity of the air at considerable altitudes above the ground distorts the sound wave and shortens the limit of audibility to the leeward, but increases it to the windward. In this way it happens that the thunder from very distant storms rarely reaches the ear. Lightning may be seen and its illumination of clouds and mist may be recognized when it is even 200 miles distant, but thunder is rarely audible 10 miles. Hence we see the need of a large number of stations if we would catch the record of every thunderstorm that happens. Probably one for every 25 square miles would not be too many. On the other hand, a few stations would suffice, at least for the nighttime, if each should report the direction and movement of every case of distant lightning.

MOVEMENTS OF WINDS AND CLOUDS IN MINNESOTA.

Mr. O. F. Rice, of Pine Island, Minn., inquires "why storm clouds appear so often on our west and winds come so constantly from the southern directions?"

As this very general question was penned in July, the Editor thinks it likely that Mr. Rice had in mind the southerly winds of the summer season in Minnesota, for the question can hardly refer to the average winds of the whole year, since in the winter time these come from the north or northwest. If one studies carefully the charts of resultant winds published regularly on Chart No. IV of the MONTHLY WEATHER REVIEW, he will perceive that in passing from the summer to the winter and *vice versa*, a gradual change takes place, not only in the direction of the winds, but also in the distribution of the temperature and barometric pressure of the lower atmosphere. These observations although made at the surface of the earth give us reason to believe that the average temperature of the mass of air above Minnesota, Manitoba, and the neighboring region is in summer much warmer than over the country to the westward of the Rocky Mountains. It will also be noticed that the barometric pressure in this central portion of the continent is, in the summer time, lower than on the Pacific Coast to the westward, and especially lower than on the Atlantic Coast to the south and east. The winds move in obedience to the differences of pressure prevailing in the neighborhood of the station. These differences may be due either to differences of temperature—by reason of which cold, dense air underflows and raises up warmer, light air—or they may be due to the differences of pressure at any level by reason of which regions of great pressure push their air into the regions of low pressure. Both of these causes are usually active in the free atmosphere, and doubtless the southerly winds of Minnesota represent the resultant effect of the general distribution of pressure and temperature in North America—not only at the surface of the ground but in the free air above the ground.

If we ascend through the lower atmosphere and study the motions of the upper air as shown by the clouds, we find a general rapid movement from west to east or southwest to northeast, showing that the motions of the upper air are largely controlled by the pressures and temperatures prevailing at the upper level. In general, a certain definite mass of air tends to flow down a gentle slope toward the region where the density of the air is less than its own at the same height above sea level. As soon as the motion begins the influence of the rapid diurnal whirl of the earth on its axis is felt by the moving air so that the upper layers above Minnesota move nearly from west to east while the lowest layer at the surface moves from the south or southwest to northeast. Therefore, while the upper clouds and the storms that they attend come from the west the lowest winds are blowing from the south.

In the winter time the distribution of temperature and pressure over North America is such as to force the cold air of Canada southward over Minnesota. The upper layers move more nearly from the west, while the lowest layers come more nearly from the north, so that at the surface of the earth northerly winds are more frequent; consequently, in the winter we do not have southerly winds below and westerly winds above, except on those dates when low pressure prevails in Canada analogous to the low pressures of the summer season.

HOURLY RESULTS FROM SELF-REGISTERS.

The Weather Bureau maintains self-registers for pressure, temperature, wind direction, rainfall, and sunshine at a very large proportion of its stations, and for the wind velocity at all of them, and the general results are given monthly in the elaborate climatological tables contributed by Mr. A. J. Henry, Chief of the Records Division. In continuation of this work Mr. Henry has prepared, for the forthcoming Annual Report